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MIDDLE COLORADO RIVER WATERSHED TEXAS

LETTER

FROM THE

ASSISTANT SECRETARY DEPARTMENT OF AGRICULTURE

TRANSMITTING

A REPORT OF A SURVEY OF THE MIDDLE COLORADO RIVER WATERSHED IN TEXAS, PURSUANT TO THE FLOOD CONTROL ACT OF JUNE 22, 1936

SEPTEMBER 14, 1943.—Referred to the Committee on Flood Control and ordered to be printed with illustrations

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LETTER OF TRANSMITTAL

DEPARTMENT OF AGRICULTURE,
Washington, August 9, 1943.

The honorable the SPEAKER OF THE HOUSE OF REPRESENTATIVES.

DEAR MR. SPEAKER: I am transmitting a report of a survey of the Middle Colorado River watershed in Texas, made by this Department pursuant to the Flood Control Act of June 22, 1936.

The report describes an investigation of a program of waterflow retardation and soil erosion prevention in aid of flood control. A program of this kind, pursuant to the flood-control acts, is recommended for installation in the watershed.

We have been advised by the Bureau of the Budget that while there would be no objection to the submission of the proposed report to the Congress, it should be understood that no commitment would thereby be made as to any early financing of a land-use and management program for the Middle Colorado River watershed in Texas.

Sincerely,

GROVER B. HILL,
Assistant Secretary.

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SURVEY OF THE MIDDLE COLORADO RIVER WATERSHED IN TEXAS

Part I

SUMMARY

The Middle Colorado River watershed includes an area of approximately 7,200 square miles lying in the central portion of the drainage basin of the Colorado River in Texas. The area includes Pecan Bayou, San Saba River, Brady Creek, and the area tributary to the main stream of the Colorado River below its confluence with the Concho River and above the mouth of Pecan Bayou.

Damages from floods aggravated by improper land use, particularly by overgrazing of range resources, constitute a serious problem. The direct flood damages which will occur on the watershed after installation of authorized flood-control measures by the War Department, but exclusive of those which occur on the main stem of the Colorado River, are estimated at approximately $662,000 annually.

A plan of improvement is proposed by the Department of Agriculture as a result of this survey which provides for retardation of waterflow and the prevention of erosion by the treatment and improved management of cropland, pasture, and woodland.

RECOMMENDED PROGRAM

A program of waterflow retardation and soil-erosion prevention pursuant to the Flood Control Act of 1936, as amended, is recommended for the Middle Colorado River watershed. The expenditure of $2,693,128 over a 20-year period for carrying out this program is recommended.

It is expected that the normal expenditures of the Department of Agriculture will continue to be made in the watershed under present soil-conservation and agricultural-adjustment programs, and that these expenditures will bring about the installation of a portion of the work contemplated under this plan. Future appropriations to finance the program herein described will, of course, take account of whatever progress has been made toward installation of the program through Department expenditures under its regular programs.

Cooperation with farmers and ranchers in the installation of this program of waterflow retardation and erosion control measures will be conditioned on appropriate coordination with the soil-conservation and agricultural-adjustment programs.

Distribution of funds.—The measures recommended for installation and the amount of funds required for the program are as follows:

Farm and ranch land treatment.—Installation of the recommended farm and ranch land treatment program will require Federal expenditures of $2,693,128 for planning, supervision, and technical services

and a portion of the materials, equipment, and labor necessary for the application of remedial measures to farm and ranch lands, the operators of which will agree to supply the balance and carry out the necessary practices under a farm plan. In addition, farmers and other individuals must furnish labor and materials having an estimated value of $666,975.

The Federal Government will incur no cost for the operation and maintenance of the program. This cost, which will amount to a total of $2,063,760 during the 20-year installation period and $206,376 annually thereafter, will be borne by farmers and other individuals.

Economic justification.—Installation of the recommended program is expected to yield the following average annual benefits:

Reduction in direct flood damage	$137, 217
Increase in farm income on land treated	1, 518, 598
Total annual benefits	1, 655, 815

The following table gives the estimated average annual costs and benefits of the recommended land-treatment program by tributary areas:

Tributary	Annual benefits		Annual costs		Total benefit per dollar total cost	Flood-control benefit per dollar Federal cost
	Total	Flood control	Total	Federal		
Pecan Bayou above Brownwood Dam	$494, 487	$39, 130	$143, 630	$28, 546	$3. 43	$1. 37
Pecan Bayou below Brownwood Dam	140, 315	15, 090	45, 846	8, 779	3. 06	1. 72
Upper main Colorado	604, 757	38, 894	171, 260	32, 958	3. 53	1. 18
Brady Creek	139, 593	14, 189	36, 647	7, 080	3. 81	2. 00
San Saba River	276, 663	29, 914	84, 711	16, 896	3. 27	1. 77
Total	1, 655, 815	137, 217	482, 094	94, 259	3. 44	1. 46

Part II

SECTION I. BRIEF DESCRIPTION OF THE WATERSHED

The Middle Colorado River watershed includes an area of 7,189 square miles lying in the central portion of the drainage basin of the Colorado River. This is approximately 17 percent of the entire drainage basin of the Colorado River of Texas. It includes the watersheds of Pecan Bayou, Brady Creek, San Saba River, and the area draining into the Colorado River between its confluence with the Concho River and the mouth of Pecan Bayou.

Climate.—The Middle Colorado River watershed lies within the subhumid section of Texas. Average annual rainfall varies from approximately 30 inches in the eastern portion of the watershed to about 22 inches in the western section. There is considerable variation in rainfall from year to year in the same localities, and prolonged drought periods as well as periods of exceptionally high rainfall are common occurrences. Although rainfall is very irregular, it is sufficient in most seasons to produce fair yields of crops on the deeper soils.

The largest portion of the rainfall usually occurs during the months of April through October, while flood producing storms occur most often in April, May, September, and October. The growing season,

which is about 220 days, is more than adequate for all crops. Heavy snowfall or frozen ground are infrequent in occurrence.

There are four types of storms which cause either local or widespread flooding: (1) Thunderstorms, (2) tropical cyclones, (3) extratropical cyclones, and (4) frontal storms. Maximum floods are usually caused by storms of the frontal type during which warm and moist air masses from the south are met by cold continental air masses moving toward the south and east.

Land use.—The predominant use of the watershed lands is for the production of livestock. Approximately 85 percent of the watershed still supports a semblance of its native vegetation, although weeds, unpalatable annual grasses, shrubs, and cacti have spread considerably since cattle, sheep, and goats overpopulated the pastures. The area is now overstocked and is being grazed at an average rate of about one animal unit to each 12 to 15 acres.

A large proportion of the watershed will never be suitable for farming because of inherent soil and climatic characteristics. In the northern section a large proportion of the arable land at one time was cultivated. The sandier sections have been crop farmed but are gradually being retired to pasture. The more fertile dark and heavy but friable clays are suitable for the production of small grains, cotton, and grain sorghums.

Physiographic divisions.—The watershed is divided naturally into five physiographic divisions (Edwards Plateau, Central Basin, Rolling Plains, West Cross Timbers, and Grand Prairie) and into four tributaries (Pecan Bayou, Upper Main Colorado, Brady Creek, and San Saba), as shown in figure 1. As will be noted, each tributary contains portions of two or more physiographic divisions. These have, in a large sense, determined the economy of the particular tributary.

Edwards Plateau is a rolling, grass covered limestone plain with shallow, dark-colored fertile soil. Nearly all of the San Saba watershed and a rather large percentage of Brady Creek are included in this area. It also extends into the western portion of the remainder of the Middle Colorado watershed. In the southern part of the area it has a live-oak aspect with some mesquite in valley areas while in the northern part the cover is a mesquite savanna.

The Edwards Plateau is an important livestock producing area. It is an area largely unsuited to the production of farm crops because of the predominance of thin, shallow, and stony soils. The relatively low rainfall, character of the land, mode of early purchase, and cheapness of land have contributed to making this a ranching area of large ownership units.

Located within this plateau and in the southeastern part of the San Saba watershed, is an instrusion of the Central Basin. Here soils, developed from sandstone and exposed and weathered igneous rocks, are sandy loams. Crop farming flourished for some years on about 10 percent of this area, but because of limited rainfall and easily exhausted soil resources, a large proportion of the land soon was returned to native cover and used for stock raising.

Vegetation in the Central Basin consists mainly of small oak trees with varying amounts of mesquite and juniper, the latter growing more extensively on the rough lands. Various grasses, with a relatively high percentage of annuals, occur in the timber, shrub, and brush growth.

The Rolling Plains occur in the northwestern portion of the watershed. This area, which originally was the best grazing area, also has deep friable clay and clay loam soils best suited to crop farming. Small cotton or grain farms occupy a high percentage of the area. The value produced per acre is higher here than in any other portion of the Middle Colorado watershed.

The West Cross Timbers area is located in the northeastern portion of the Middle Colorado River watershed. Because the sandy soils were easily worked cultivation of this area began at a relatively early date. Early settlement also was facilitated by the availability of post oak and blackjack oak for building. As fertility decreased and erosion increased, there has been a trend toward converting worn-out cropland to pasture land and the production of more livestock.

The Grand Prairie area occupies a relatively small section along the eastern edge of the watershed. It is a dissected limestone prairie characterized by relatively shallow soils and steep slopes. Ranching is the chief industry.

Total population of the Middle Colorado watershed is about 88,000 persons. Towns are small and the rural areas are sparsely settled, averaging only about nine persons per square mile.

TRIBUTARY AREAS

The Middle Colorado River watershed was divided into four tributary areas for the purpose of analyzing the effect of possible remedial programs on flood flows and flood damages. These four tributaries and their approximate watershed areas are as follows:

	Square miles
1. Pecan Bayou	2142
2. Upper Main Colorado	1,840
3. Brady Creek	813
4. San Saba River	2,394

Pecan Bayou, Brady Creek, and the San Saba River are the only major tributaries on which significant effect of agricultural remedial programs on main stem flood damages can be measured.

Main stem damages in the upper main Colorado are caused principally by floods that originate on the land above the area included in this survey. Measurement of the effects of treatment of the portion of the watershed under survey on these main stem damages would be costly and difficult, and the resulting reduction probably would be of minor importance. The magnitude of the probable benefits was believed to be too small to justify the expenditure of technical labor and funds which would be necessary for their determination. In the Pecan Bayou watershed main stem damages below Lake Brownwood will be small because of the control over flood flows provided by Brownwood Dam.

Sample minor tributaries were selected in Pecan Bayou, San Saba River, and Brady Creek watersheds on which to determine the effect of remedial programs on damages on minor tributaries in the respective natural physiographic divisions. The reductions in flood run-off for the respective physiographic divisions in the watershed were used to determine main stream reductions on Pecan Bayou, Brady Creek, and San Saba River subwatersheds only. Pertinent information relative to these subwatersheds is presented in the following discussion.

Pecan Bayou.—Pecan Bayou watershed occupies the northern portion of the area surveyed. It includes parts of three natural physio-

graphic divisions, namely: Rolling Plains, Edwards Plateau, and West Cross Timbers. Brownwood Dam, which is located below the confluence of Jim Ned Creek and Pecan Bayou, and which controls the drainage of about 70 percent of the tributary watershed, reduces main stem flood damages below the dam to a negligible quantity. Additional protection to this area will be provided by the increase in height of the dam and enlargement and improvement of the spillway which were recently authorized.

Brady Creek.—Brady Creek is a tributary of the San Saba River. This small tributary watershed, which lies in the west-central portion of the survey area, is composed of an isolated section of Rolling Plains surrounded by a higher-lying Edwards Plateau area. The friable fertile soils of the Rolling Plains are used for growing general farm crops. A considerable portion is used almost entirely for the production of feed crops which are used to supplement the forage provided by the associated rangeland. The Edwards Plateau has a live-oak, shin-oak aspect and the associated short grasses are used for grazing.

The War Department has been authorized to construct a floodway to protect the lower part of the business section of the town of Brady. This improvement should reduce considerably future flood damages to the town. Very little main-stream flood damage occurs below the town of Brady because in this reach Brady Creek flows through a gorge.

San Saba River.—The San Saba River watershed is a long, narrow tributary watershed which begins in the extreme western section of the area studied, and extends in a northeasterly direction to the confluence of San Saba River and Colorado River near the eastern border of the area. Approximately 48 miles (mile 45 to mile 93) of the channel of this river is gorge-like. Three natural physiographic areas occur in the San Saba sub-watershed. Most of the watershed is composed of Edwards Plateau but it also includes small areas of Central Basin and West Cross Timbers.

Soils.—Ten soil groups were recognized in the examination of the watershed. These groups were based on hydrologic and productivity characteristics of the soils.

ECONOMY OF THE WATERSHED

The entire watershed since settlement has been devoted predominantly to stock raising. Although grazing of cattle has been general since 1850, large numbers of cattle and sheep or goats were not present before 1880. Permanent settlement occurred about that time and a gradual increase in population and in amount of land under cultivation has taken place during the last 50 or 60 years. Density of population ranges from approximately 5 persons per square mile in the Edwards Plateau to about 22 persons per square mile in the West Cross Timbers area.

Types and sizes of farms.—The rather numerous types and sizes of farms in the watershed may be grouped into four general major types, as follows:

(1) Small crop farms.
(2) Large crop farms.
(3) Small ranches.
(4) Large ranches.

Farms predominate in the Pecan Bayou and Upper Main Stream areas, where they occupy 57 and 56 percent, respectively, of these watersheds. Ranches are most important in the San Saba watershed where they occupy 90 percent of the area, and include 36 percent of the total number of operating units.

Large farms, those over 200 acres in size, occupy 40 percent of the Pecan Bayou above Brownwood Dam and Upper Main watershed areas, and 24 percent of the Pecan Bayou watershed below Brownwood Dam. These farms are usually general in type, growing cotton and small grains, and raising some livestock.

Small farms, those less than 200 acres in size, occupy 17 percent of the Pecan Bayou area, These usually are cotton or subsistence farms on which few livestock are kept.

The large ranches, few in number but occupying 75 percent of the San Saba tributary area, usually are devoted to the grazing of cattle, sheep and goats with only occasional cultivated fields of small grain used principally for growing supplementary pasture or feed crops.

Present net incomes on the small farms, depending upon their organization and location, range from less than $250 up to $750 annually. On large farms the annual income is between $650 and $3,000. Small ranches usually have a net annual income of between $600 and $2,500, while large ranches have incomes between $2,000 and $22,000, depending on their size and organization.

Farm tenancy.—Farm tenancy is not a serious problem in the Middle Colorado River watershed. Only 21 percent of the area of Pecan Bayou, 8 percent of Brady Creek and 7 percent of the San Saba River is being operated by tenants. However, 16 percent of Pecan Bayou, 14 percent of Brady Creek and 12 percent of the San Saba is operated by so-called owner-additional tenants. These owners lease pastures for grazing in addition to the land which they hold. This system is not conductive to conservative stocking practices.

SECTION II. FLOOD PROBLEMS AND RELATED DAMAGES

Flood damages on the Middle Colorado result primarily from the inundation of either crop or pasture lands. Little industrial development has occurred within the flood plains and only the very largest floods have caused large urban or nonagricultural damages.

Valuable agricultural lands or large damageable values occur only in certain reaches of the streams and in small tributary valleys which are subject to small flash floods. Bottom-land areas are used extensively for crop production whenever possible because of the lack of other arable land. Cotton, corn, alfalfa, and small grains are extensively grown.

The flood problem can be divided into that existing on third order tributary streams, that on the main stems of San Saba River, Brady Creek, and Pecan Bayou, and that on the main stem of the Colorado River. Local thunderstorms covering from 100 to 500 square miles cause severe flooding on small tributaries, while producing only small rises on the main stems. The frontal storms and cyclonic disturbances, blanketing large tributary areas or a large proportion of the Middle Colorado watershed, result in severe flooding, not only in small tributary streams but also in the main stems of the major tributaries and of the Colorado River.

Completion of three structures which have been authorized will have a decided effect on flood problems of the Middle Colorado. Brownwood Dam, on Pecan Bayou, is to be raised and strengthened to reduce flood damage on Pecan Bayou below the dam by an amount estimated at 70 percent. Construction of a water supply and flood-control dam on Hords Creek above Coleman will further modify flooding on Pecan Bayou. It is assumed that this reservoir will control floods as large as any of record originating above the dam. A floodway is authorized for construction at Brady which is designed to protect all urban and municipal property in that city from future flood damage.

In the evaluation of the remedial program recommended in this report it has been assumed the improvements that have been authorized are completed and in operation.

FLOOD DAMAGE

Present average annual flood damage in the Middle Colorado River watershed, exclusive of damage on the main stem of the Colorado River, is estimated at approximately $662,000. In all damage evaluation emphasis was placed upon probable future damages rather than upon past damages which might not be recurrent. Main stem and tributary damages, classified according to type as (*a*) crop and pasture, (*b*) other agricultural, and (*c*) nonagricultural damages, are shown for Pecan Bayou, Brady Creek, upper main Colorado, and San Saba watersheds in table 1. This tabulation indicates that a large proportion, 76 percent, of the total damages occur on small tributary streams.

TABLE 1.—*Estimated average annual flood and related damages, Middle Colorado River watershed, after installation of authorized flood-control projects*

Tributary and type of damage	On sub-tributaries	On main stem	Entire tributary
Pecan Bayou above Brownwood Dam:			
Crop and pasture	$120,938	$25,465	$146,403
Other agricultural	10,574	4,424	14,998
Nonagricultural		24,892	24,892
Total	131,512	54,781	186,293
Pecan Bayou below Brownwood Dam:			
Crop and pasture	49,484		49,484
Other agricultural	5,980		5,980
Nonagricultural			
Total	55,464		55,464
Upper main Colorado:			
Crop and pasture	145,490	(1)	145,490
Other agricultural	5,231		5,231
Nonagricultural			
Total	150,721	(1)	150,721
Brady Creek:			
Crop and pasture	49,957	16,293	66,250
Other agricultural	5,366	4,544	9,910
Nonagricultural		1,900	1,900
Total	55,323	22,737	78,060
San Saba River:			
Crop and pasture	86,648	32,079	118,727
Other agricultural	35,318	25,823	61,141
Nonagricultural		11,807	11,807
Total	121,966	69,709	191,675
Watershed total [2]	514,986	147,227	662,213

[1] Damages on main stem omitted because they are caused primarily by run-off from land outside of the area under present consideration.

[2] Does not include main-stem damages for the upper main Colorado subwatershed. See footnote 1.

Agricultural damage.—Damage to crops and pastures is by far the most important type of damage. Sedimentation damages, which are relatively insignificant, have been omitted.

Crop and pasture damages are based on losses of crops and pasture because of reduction in yield or total destruction and increased expense for repeated planting or cultivation together with proper allowance for the value of substitute crops harvested and any saving in harvesting or other expenses.

Other agricultural damages include loss of livestock, and damage to buildings, fences, drainage ditches, farm roads, stored crops, and other agricultural property. Estimates of agricultural damages are based on schedules obtained from occupants of the flood plains and on anticipated area and frequency of inundation.

Nonagricultural damage.—Nonagricultural damage includes the expected future damage to existing urban and public property such as roads, bridges, telephone lines, gas and oil pipe lines, etc. Nonagricultural damage estimates were obtained by appraisals and from data assembled by the United States engineers and local agencies.

Flood damages not evaluated.—Certain intangible damages such as losses resulting from interruption of utilities, rental of property, loss of wages of employees, loss of recreational facilities, etc., were not evaluated in monetary terms.

EROSION DAMAGES

Erosion of upland, particularly cultivated fields and heavily grazed pastures, directly and permanently reduces the productivity of the land. Each year's erosion represents a continuing damage as soil losses are cumulative until all economic usefulness of the land is lost.

Although these losses are moderately large and severely affect farms in certain portions of the area, the damage has not been evaluated.

The amount of erosion will be reduced by installation of the measures included in the flood control program recommended. The recommended treatment also will result in the stabilization of crop yields.

SECTION III. CURRENT AND PAST ACTIVITIES HAVING FLOOD REDUCTION BENEFITS

The remedial flood-control program recommended in this report takes cognizance of the activities and accomplishments of other agencies. Coordination of this program with activities of agencies which either directly or indirectly are effecting flood reductions is considered of paramount importance. Conservation measures installed throughout the watershed by these agencies have as their primary purpose water conservation and to the extent they are installed will supplement the program recommended herein and in certain cases bring about the installation of measures equivalent to those recommended in this report.

War Department.—The Corps of Engineers has under preparation a flood control survey report on the Colorado River. Survey reports on several individual tributaries also have been submitted, particularly House Document No. 441 on Brady Creek and House Document No. 370 on Pecan Bayou. The recommendations in these two reports have been accepted and the operations have been authorized subject to appropriations being made available.

Construction of a floodway at Brady, on Brady Creek, which will protect the town of Brady from flood damages also is authorized.

This authorization of a floodway includes improvement of the existing channel of Brady Creek, construction of levees and floodwalls and rectification of bridges and appurtenant facilities at Brady, Tex., at an estimated Federal cost of $825,000, subject to provision by local interests of rights-of-way and other services. No effect of these measures on other areas of Brady Creek is claimed.[1]

Two improvements are authorized for Pecan Bayou. A dam and reservoir is authorized for construction about 7 miles above Coleman, Tex., at an estimated initial construction cost of $560,000 and an annual maintenance cost of $2,000. This dam will provide for control of floods and conservation of water on Hords Creek.[1] It is estimated by the United States district engineer that about 62½ percent of the direct damages to agricultural and other property on Hords Creek below the dam will be controlled.

Enlargement of the existing dam, and improvement of the existing spillway at Lake Brownwood [2] on Pecan Bayou, Tex., to provide additional storage for the control of floods and the conservation of water is authorized. This project has an estimated initial cost of $2,500,000. It is estimated that the completed dam will reduce direct flood damages on Pecan Bayou below the dam by about 70 percent and also provide $18,000 additional annual benefit on the main stem of the Colorado River.

Soil-conservation districts.—The State of Texas has authorized the organization and operation of soil-conservation districts. Under this law organization of four districts within the Middle Colorado has been completed, their locations being shown in figure 2. Each district, in cooperation with the Soil Conservation Service and other agencies, assists in the planning and installation of measures on cooperator's land. These measures are designed primarily for soil and water conservation, water conservation being of especial importance in this area of limited rainfall.

Although these districts have been operating but a short time, about 52,000 acres had been planned and the installation of treatment started as of December 31, 1941. Execution of the agreements is slow due to lack of funds and facilities for speedy operations. The measures being installed will provide effective water conservation and contribute to a reduction in flood run-off and flood damages.

County and State land-use planning committees.—County and State land use planning committees are composed of farmers who are organized to develop a coordinated plan of desirable land use within their respective counties or States. They cooperate with neighboring county committees in planning for the improvement of agricultural conditions. Various agencies of the Federal and State Governments cooperate by furnishing the county committees advice, information, and unpublished data.

Agricultural Adjustment Agency.—Approximately 85 percent of the operating units within the Middle Colorado River watershed are being farmed in cooperation with the agricultural conservation program of the Agricultural Adjustment Agency. This program aids in conserving farm resources as well as increasing farm income and maintaining proper supplies of farm products through benefit payments

[1] H. Doc. No. 441, 76th Cong., 1st sess., Brady Creek, Tex.
[2] H. Doc. No. 370, 76th Cong., 1st sess., Pecan Bayou, Tex.

and other means. Through payments it enables farmers to plant soil-building crops, carry out soil-building practices, defer grazing, improve pastures and construct stock ponds. Many of these measures contribute to flood control.

Farm Security Administration.—Farm Security Administration loans money, at an equitable interest rate, to distressed farmers when a well-developed plan for the farm unit is accepted by the owner or operator. These plans include waterflow retardation and erosion control measures applicable to the area.

Water facilities.—The water facilities program loans funds and supervises construction of needed water supply facilities on farms. A stipulated plan of conservation work is specified for cooperating farms and ranches to insure retention of the productive capacity of the land and repayment of the loan. A project at Coleman, Tex., cooperates with the soil conservation district and another operates near Eden, Tex.

Central Colorado River Authority.—The Central Colorado River Authority a local organization authorized by the State legislature, is particularly active in the Coleman soil conservation district. This organization, assisted in small part by tax remission by the State of Texas, has procured equipment and led in the construction of adequate surface water supply reservoirs for several towns where groundwater supplies were lacking. It has accumulated equipment and operating funds and cooperates with farmers and landowners in constructing both water facilities and soil and water conserving measures by furnishing the equipment at the cost of its operation. At present (1942) this organization is working only on farms where plans of the soil conservation district have been accepted. The Central Colorado River Authority has proved the ability of a community to assist itself in bettering conditions through organization and acceptance of responsibility.

The Central Colorado River Authority has prepared a plan for the most economic use of the surface water supplies of Coleman County and surrounding area. Hords Creek dam is one of the big projects included in the Coleman plan of water conservation.

Other activities.—Other projects and agencies which are engaged in work resulting in some measure of water flow retardation and erosion prevention are: The Texas agricultural experiment station; the State agricultural extension service; the vocational agricultural program; and the State department of agriculture. These agencies have done much in educating farmers to realize the value of soil and water conservation practices.

SECTION IV. THE PROPOSED REMEDIAL PROGRAM

Selection of a remedial program for waterflow retardation and soil erosion prevention in a watershed in which nearly all of the land is in farms or ranches, such as the Middle Colorado River watershed, must give consideration to the effect of the recommended measures on farm and ranch operation and to the probable acceptance and maintenance of these measures by farm and ranch owners and operators. Measures which are not of practical value to the land operator would soon be discontinued unless exorbitant annual subsidy and rigid supervision was provided. Selection of the measures recommended in this report,

therefore, has been based upon consideration of their probable acceptance and maintenance as well as their effect on run-off.

In this area of low and uncertain rainfall the measures recommended are concerned with the control of erosion and the conservation of water in order that run-off in years of excessive rainfall may be stored and used in years of deficient precipitation. Experimental results indicate that soil moisture is the major limiting factor of production. Some of the remedial measures recommended by the soil conservation districts, that are moisture conserving, that are practical of application, that are acceptable to land operators, and that give maximum economical results in run-off and waterflow retardation and soil erosion prevention, form the basis for an agricultural program in aid of flood control.

Measures proposed herein will be applied in proper relation to the productive capability of the land and the economic potentialities of the individual operating agricultural units. Integrated plans will be made for each unit on the basis of conservation and range surveys and analysis of the farm business to insure proper distribution of measures and permanent maintenance of structures.

REMEDIAL MEASURES RECOMMENDED

The remedial program involves 4 major items; namely, (1) improvement of range cover, (2) installation of mechanical measures on both range and cultivated land, (3) conversion of severely eroded lands to pasture, and (4) adequate educational and supervisional service to insure proper installation and maintenance of the practices and structures recommended.

Improvement of range cover.—The major control measure needed to provide the desired improvement in range cover is an immediate reduction of approximately 50 percent in the number of animal units of livestock now being grazed on the ranges and pastures of the watershed. Reductions on individual grazing units, which may vary from this percentage, should be based on a careful survey and analysis of the cover and its present utilization. They should provide for the leaving of approximately 25 percent of the forage for range protection and reseeding.

Management of both pastures and livestock in light of the best present information is recommended. Close attention should be given to proper salting and watering practice, seasonal utilization of grasses, deferred and rotational grazing, and careful control of grazing during critical periods. Thorough discussions of these measures are available in many publications.[3]

The above recommendations are particularly applicable to the ranches but in some measure are also necessary for farm pastures. On farms there are usually adequate supplies of forage to carry present stock but supplementary feeding in pens and restriction of grazing to favorable periods, are recommended.

The systematic and complete utilization of all available supplementary feed, along with proper grazing management and increased yield of feed crops accompanying adoption of the recommended

[3] The Western Range; Texas Agricultural Experiment Station Bulletins; New Mexico Agricultural Experiment Station Bulletins.

practices should permit the necessary reduction in grazing without disposal of a proportional number of livestock. Reduction in the intensity of grazing together with adoption of the other remedial measures will permit rapid recovery of range grasses. It is assumed that the present level of livestock production may be restored by the end of 10 years after initiation of the program.

Measures on cultivated lands.—Physical factors such as soil type, slope, degree of erosion, productivity, and cover determine the type and intensity of treatment to be employed on cultivated land.

Terracing.—Three types of terraces are recommended: (1) Closed-end level terraces are recommended for cultivated, absorptive soils where the slope is less than 2 percent. These are expected to retain all rainfall and store it in the soil for crop use. (2) On less absorptive soils and on slightly steeper gradients level open-end terraces are recommended. (3) Graded terraces of standard design are recommended for use under certain conditions on slopes with over 2-percent gradient. Outlet protection will be necessary for both the latter types. Either individual outlets upon good pasture areas or collective outlets either of meadow type or of hydraulically designed channel type will be used.

Contour cultivation.—Contour cultivation is recommended on all cultivated land except on nearly level or alluvial land. A significant proportion of present cropped land in the watershed now supports cross-slope cultivation, but this is not as effective as true contouring. Experiments show that soil loss with cultivation up and down slope is double that with contour cultivation,[4] while water losses are in the ratio of 1.60 to 1.[5]

Strip cropping.—While strip cropping is recommended in this area for land requiring complex practices and on terraces during the first year or two after construction, little benefit in water conservation is expected from their use. The small grain used as strip crops will in effect be borrowed from present acreages. However, strips are effective in reducing soil losses and retarding flash run-off from cultivated fields with resulting benefit to the areas stripped.

Stubble mulching.—Stubble mulching consists of so tilling the soil that the plow layer is prepared for cropping without covering the stubble or vegetative litter remaining from the previous crop. The retention of the crop residue on the surface greatly facilitates the infiltration of rainfall and decreases erosion. This practice is recommended on about one-third of the participating cropland in the tributaries considered. This will include a large proportion of the small grain land, some weedy fallow land, and portions of the grain sorghum and sudan lands.

Contour furrows and ridges.—Contour furrows and ridges are recommended for approximately 3 percent of the pasture lands. Ridges are recommended for nearly level areas and for pastures requiring clearing while furrows will be constructed on overgrazed or bare sites to facilitate the recovery of grasses. These small water-holding devices are suitable for sod grass areas (buffalo or mesquite grass) with slopes of less than 5-percent gradient. They retain rainfall after storms and

[4] Soil and Water Conservation Investigations SCS-ERS-3, July 1937, Red Plains Soil Conservation Experiment Station, Guthrie, Okla.

[5] Water and Soil Conservation Experiments at Spur, Tex.; Bull. No. 587, July 1940, Texas Agricultural Experiment Station.

increase infiltration by improving grass cover. Contour listing is recommended for range improvement in some areas.

Conversion of unsuitable cultivated lands to pasture.—Only a small percentage of presently cultivated lands are recommended to be retired and used for pasture. These include certain fields or portions of fields which have been eroded severely due to slope and soil conditions and some few which have been cultivated but which were originally too shallow or infertile for continued cultivation.

On about three-fourths of the area to be retired, all crop residue possible will be allowed to remain and the land protected from close grazing for 4 or 5 years. On the remainder, sand dropseed or other easily established cover grass will be sown on the area protected from heavy grazing until recovery of the range perennials ensues.

Contour furrowing, ridging, or listing will be installed on these areas to conserve all moisture possible in order to encourage vegetative growth.

RECOMMENDED LAND UTILIZATION

A generalized picture of the recommended land utilization and the general intensity of application of remedial measures by areas is presented in figure 3. This figure shows the delineation of the watershed into areas within which certain classes of farming and ranching are most appropriate and in general denotes the intensity of remedial measures necessary to attain a permanent system of farming. It was noted that in nearly all cases the present type of farm or ranch is well suited to the locale and that, even though maladjustments may have occurred in the past, the present trend is toward the most appropriate use. The small crop or subsistence farms, common to the Central Basin and West Cross Timbers areas, are now gradually being consolidated into larger holdings and the number of livestock increased. Encouragement of these adjustments should be continued by all agencies interested in the establishment of proper land use and in the maintenance of watershed values.

TABLE 2.—*Recommended land utilization and treatment based on occurrence of general land use capability classes, Middle Colorado River watershed*

LAND SUITABLE FOR CROP FARMS

Capability classes	Soil groups and general land characteristics	Treatment of cultivated land	Treatment of pasture	Treatment of woodland
Class I: Suitable for crop production without special practices.	3. Deep bottom land soils: Occasionally overflowed, some deposition and scour but no detrimental erosion.	Production of adaptable crops	Pasture management; brush control; weed control.	Protect from grazing sufficient area for future farm needs; improvement cutting.
Class II: Suitable for crop production with simple practices.	1. Friable surface soil, clay subsoil. 2. Heavy surface soil, heavy clay subsoil. 5. Shallow friable soil, soft subsoil. 10. Sandy surface soil, friable subsoil. 4. Sandy surface soil, friable to heavy subsoil (under 1 percent slope). Slight erosion on slopes under 3 percent.	Terrace level closed ends or partially closed ends on steeper slopes; contour cultivation, crop rotation; stubble-mulch small grainland.	Pasture management; contour furrow or ridge; removal of mesquite; trees as feasible; establishment of adaptable grasses on retired land.	Protect from grazing sufficient area for future needs; improvement cutting.
Class III: Suitable for crop production with complex practices.	1. Friable surface soil, clay subsoil. 2. Heavy surface soil, heavy clay subsoil. 3. Deep sandy surface soil, friable to heavy subsoil. 4. Sandy surface soil, friable to heavy clay subsoil. 5. Shallow friable soil, soft subsoil. 10. Sandy loam surface, friable subsoil; moderate erosion on slopes below 5 percent.	Terrace, level, partially open or open ends and for variable grade, emptying on grass; contour tillage crop rotation, stubble-mulch on small grainland; strip crop, crop rotation, legumes, on more sandy soils; retire limited areas of steeper and severely eroded areas.	Pasture management; contour furrow or ridge all except deep sandy soils; removal of mesquite, trees, oak brush as feasible; establishment of adaptable grasses on retired land.	Protect from grazing sufficient area for future farm needs; improvement cutting.

LAND SUITABLE FOR LIVESTOCK FARMS				
Class IV: Suitable for livestock production and requiring moderate restrictions in land use, and some special practices on cultivated land.	2. Heavy surface soil, heavy clay subsoil. 4. Sandy surface soil, friable to heavy clay subsoil. 5. Shallow friable soil, soft subsoil. 6. Shallow heavy soil, underlain by limestone, or hardened caliche or large limestone rocks. 7. Stony soils, limestone. 7a. Stony soil, sandstone. 8. Rough stony land, limited. 9. Overflow land, nonarable, limited. 10. Sandy loam surface, friable subsoil; limited; moderate to severe erosion.	Careful selection of cultivated land; less than 5 percent slope; retire rolling, shallow, and severely eroded soils; terrace level open ends or variable grade, empty on grass; contour cultivation; crop rotation; occasional diversion terrace.	Recovery stocking and pasture management; contour furrow or ridge; removal of mesquite trees, oak brush as feasible; establishment of adapted grasses on retired land.	Protect from grazing sufficient area for future farm needs; improvement cutting.
LAND SUITABLE FOR RANCHES				
Class VI: Land suitable for livestock production, requiring moderate restrictions in land use and special practices on cultivated land and limited special practices on pasture.	4b. Shallow clay loam surface, somewhat stony, heavy red subsoil. 5. Shallow friable soil, soft subsoil. 6. Shallow heavy soil, underlain by limestone. 7. Stony limestone soil. 7b. Stony limestone and sandstone soils. 8. Rough stony land, limited. 9. Overflow (nonarable); moderate to severe erosion.	Careful selection of cultivated land; less than 5 percent slope; retire rolling, shallow, and eroded soils; treat limited areas as class II, treat remainder as class III.	Recovery stocking and pasture management; contour furrow or ridge limited areas of deeper soils; eradicate mesquite trees and brush as feasible; establishment of adaptable grasses on retired land; eradicate cedar on deeper soils and slopes under 10 percent.	Protect from grazing sufficient area for future ranch needs; improvement cutting. Retention of cedar on limited critical areas.
Class VII: Land suitable for livestock production, requiring severe restrictions in land use, complex practices on cultivated and limited special practices on range land.	4a. Deep sandy surface soil, dense heavy clay subsoil (granite origin). 4b. Shallow clay loam surface, somewhat stony, heavy red subsoil. 5. Shallow friable soil, soft subsoil. 6. Shallow heavy soil, underlain by limestone or hardened caliche. 7. Stony limestone soil (limited). 7a. Stony sandstone soil (limited). 7b. Stony limestone and sandstone soil (limited). 8. Rough stony land. 9. Overflow land (nonarable); moderate to severe erosion; rolling to hilly areas.	Careful selection of cultivated land; less than 5 percent slope; retire rolling, shallow, gravelly, and eroded soils; treat remainder as class III.	Recovery stocking and pasture management; contour furrow or ridge very limited areas of deeper soil; establishment of grasses on retired land; removal of mesquite trees and brush as feasible; gradual eradication of cedar on limited areas of deeper soils on slopes less than 10 percent.	Protect from grazing sufficient area for future needs of ranch; improvement cutting; retention of cedar on extensive critical areas.

Table 2 shows the general treatment recommended for the various delineations. Detailed surveys are necessary to make adequate adaptation to individual farms. However, the general intensity of application of necessary and recommended remedial measures is reflected in the map and table.

PARTICIPATION IN THE RECOMMENDED PROGRAM

At present there is no apparent insurmountable difficulty in installing the recommended remedial measures on low-income farms. It has been demonstrated that practically all measures can be applied without a considerable outlay of cash and that off-season farm labor is usually capable of installation and maintenance of the program. There are problems, however, which have a decided effect upon ability of farm and ranch owners and operators to participate. High mortgage indebtedness and the present system of leasing are two of these problems.

Mortgage indebtedness.—Land values are high in the watershed. Grazing land sells at from $10 to $30 per acre while farm land sells at from $35 to $50. In a country where from 10 to 50 acres are needed to support one animal unit this capital investment is very high. This means that a landowner, in order to maintain the present standard of living and to pay for the land, must put all of the grazing pressure possible on his ranges. This means, in effect, that he must depreciate his capital to meet fixed charges against it. It is recommended that agencies interested in assistance to farmers in refunding indebtedness put forth efforts to reduce fixed charges to the minimum.

Present leasing arrangements.—The lessee is commonly forced to utilize fully all available forage in order to pay the high leasing charges and make any profit. There is need for a closer relationship between range carrying capacities and rental charges. Rental rates should conform more closely to safe carrying capacities and leases should contain adequate safeguards against range depletion through overstocking.

Estimation of participation.—Representatives of the Soil Conservation Service operating in the watershed were interviewed regarding the probable extent of local participation in the recommended remedial program. It was the consensus of their opinion, which agreed with the estimates of the survey party, that 65 percent of the farms and ranches would cooperate in establishing and maintaining a land use and management program such as that recommended in the soil conservation districts in 20 years and that it was doubtful, under present or similar conditions of ownership and attitude if any significant proportion of the remainder would cooperate after 20 years. This estimate was based upon past experiences and a thorough knowledge of the problems of education and application of remedial measures of this sort. It was not expected that public opinion would change sufficiently to insure 100-percent cooperation through passage of regulations in regard to land use and treatment.

It was reasoned that, since the recommended watershed program in aid of flood control contains measures similar to those in the present district programs, participation would be of about the same order unless special measures to increase this participation were adopted. Consultation with technical personnel revealed that 65 percent of the units would comprise nearly all of the units except those hampered

by ownership or tenancy problems or on which the owners were opposed to regulation of any sort. Completion of all work on the last of the farms and ranches likely to participate might extend beyond 20 years.

To be conservative, therefore, it was estimated that if sufficient technical personnel were available to plan and supervise the program at least 50 percent of all farms and ranches would be completely treated in 20 years. The estimated participation by tributaries is as follows:

Tributary	Acres	Number of farms and ranches
Pecan Bayou above Brownwood Dam	469,858	1,169
Pecan Bayou below Brownwood Dam	207,404	361
Upper main Colorado	538,825	1,432
Brady Creek	257,134	208
San Saba	762,005	555
Watershed total	2,235,226	3,725

SECTION V. PHYSICAL EFFECTS OF THE PROGRAM

Installation and proper maintenance of the remedial program recommended in this report will result in a definite reduction in the present amount and rate of run-off and erosion. This program will also result in improved economic conditions in the area, affecting not only the individual farm or ranch operator, but also resulting in a more stable and valuable agricultural economy for the watershed as a whole.

EFFECT OF THE PROGRAM ON FLOODS

The flood problem and the effect of the program are modified to some extent by certain flood-control measures, construction of which has been recommended by the United States engineers and authorized by Congress. These are as follows: (1) Raising of Brownwood Dam; (2) construction of Hords Creek Reservoir above Coleman, Tex.; and (3) construction of a floodway on Brady Creek at Brady, Tex. The United States engineers may also recommend the construction of a flood-control reservoir on the San Saba River above Menard, Tex.

In view of the authorization for construction of the above-mentioned projects, the evaluation of the program of the Department of Agriculture is based on the assumption that the Brownwood and Hords Creek Dams and Brady Creek floodway are complete and in operation. Main-stem benefits, as calculated in this report, are those that will accrue to the recommended program after the installation of these works.

By far the greatest proportion of flood damages, upon which a watershed-treatment program can exert any appreciable effect, occur on the minor or subtributaries within the several natural physiographic divisions of the watershed. The damages and the existing and possible future conditions on watersheds are relatively similar in a given physiographic division but differ between divisions. For these reasons the emphasis in evaluating the effect of the recommended program on floods and their resultant damages was placed on determining

the benefits that would accrue through reducing the subtributary damages. When significant main-stream benefits could be determined (such as Pecan Bayou, Brady Creek, and San Saba River), these benefits were determined separately and added to those for the subtributaries.

EFFECTS ON SUBTRIBUTARIES BY PHYSIOGRAPHIC DIVISIONS

Eight sample subtributaries were selected as representative of the physical conditions existing in the various subtributaries and physiographic divisions in the watershed. The effects of the remedial programs were determined on these subtributaries and the benefits accruing from these effects were expanded to the respective physiographic divisions. The selected sample subtributaries, their drainage areas, and the areas they represent are as follows:

Subtributary	Drainage area, square miles	Area represented
Bachelor Creek	31.80	Rolling Plains in north and northwest portion of watershed above Brownwood Dam.
Oak Creek	22.55	Rolling Plains in central and southern portion of watershed.
Hog Creek	72.91	West Cross Timbers where subtributaries are relatively large and form a part of an intricate drainage system.
Whistle Creek	3.10	West Cross Timbers where subtributaries are relatively small and discharge directly into main streams.
West Fork Katemcy Creek	17.60	Central Basin rolling.
Clear Creek	23.58	Edwards Plateau rolling in northern portion of watershed on Pecan Bayou.
Cottonwood Creek	27.00	Edwards Plateau rolling in central portion of watershed. Vicinity of Brady Creek.
East Fork Las Moras Creek	23.28	Edwards Plateau rolling in southern portion of watershed.

It will be noted that subtributaries were not selected to represent the rough stony areas of the Central Basin or Edwards Plateau divisions. It was believed that present flood damages, or the flood-control benefits that would result from any remedial programs that could be devised for these areas, would be unimportant. No attempt was made to plan a remedial program in detail for these areas or to evaluate the minor damages or benefits that occur or would accrue on them.

Rainfall records obtained at Abilene, Tex., were examined and those for the 11-year period, 1930–40 were selected as representative of the entire period of record. It was assumed that each rain that had occurred at Abilene during the selected period could be duplicated in intensity, pattern, and depth on each subtributary selected for evaluation.

The floods that would be produced if each sample subtributary was subjected to the series of storms recorded at Abilene, both with present watershed conditions and with conditions as they would exist with the recommended program in effect were calculated. Flood run-off was estimated by application of the infiltration theory of run-off in conjunction with infiltration data obtained by the application of artificial rainfall to plots representing the more important combina-

tions of soil and cover found on the watershed. The relationship between flood magnitude and area inundated for each of the subtributary areas was derived for each of these floods by the use of channel and valley cross sections, unit hydrographs, concordant flood profiles, and hydraulic computations. Estimates of the areas inundated were then used in determining flood damages under present conditions and with the remedial program in effect. Figure 4 shows the calculated effect of the recommended program on the subtributaries and the several physiographic divisions in terms of percentage reduction in present calculated flood volume.

EFFECTS ON MAIN STEMS OF PECAN BAYOU ABOVE BROWNWOOD DAM, BRADY CREEK, AND SAN SABA RIVER

In addition to determining the effects of the program on the subtributaries and physiographic divisions, the effects were calculated for the main stems of Pecan Bayou above the Brownwood Dam, Brady Creek, and the San Saba River. Pecan Bayou has but one stream-flow record, that at Brownwood. This covers the period from 1923 to date but stream flow since 1932 has been affected by the operation of the Brownwood Dam. There are no reliable records for Brady Creek. Two stations on the San Saba located at San Saba and Menard have records since 1905 and 1932, respectively. The evaluation of the effect of the remedial program on floods on these main streams was made by selecting the period from 1924 to 1940 inclusive, on Pecan Bayou and Brady Creek, and 1918 through 1940 on the San Saba. After determining the dates of all floods that occurred on these streams during these periods the average depth of rainfall, over the watersheds, that produced these floods was calculated. This depth of rainfall was obtained by Horton-Thiessen polygon weighting of the rainfall records available on the watersheds. The distribution of physiographic divisions above any point along the streams was known as was the calculated run-off per unit of area of each division with and without the remedial program obtained by the subtributary evaluation. From these data a relationship between present and future run-off and rainfall depth was determined for several points along the main stems of these major tributaries. This relationship, when applied to the depths of rainfall in the flood-producing storms in the two selected records, produced calculated present and future flood volumes at the selected main stream points. These volumes were converted to stage heights on Pecan Bayou and Brady Creek by use of unit hydrographs. On the San Saba River the calculated volumes of run-off were adjusted by the ratio of actually observed to calculated volumes under present conditions for the several floods for which adequate hydrographs were available in the stream-flow record prior to conversion to stage heights. By use of concordant flood profiles and valley cross-sections the areas inundated under present and future conditions by the floods in the series was obtained by reaches. This information was then used to determine flood damages under present and future conditions.

Figure 4 shows the calculated percentage reduction in flood volume resulting from the installation of the remedial program above the main stream evaluation centers used.

SEDIMENTATION

The volume of sediment deposited annually in each reservoir in the watershed was estimated by means of detailed and reconnaissance surveys. Preliminary calculations indicated total benefits resulting from reductions in sedimentation were inconsequential and a more accurate determination was not made. The benefits presented in this report, therefore, do not include any benefit from possible decreased sedimentation in reservoirs.

SECTION VI. BENEFITS OF THE REMEDIAL PROGRAM

Direct flood-control benefits are measured by the difference between flood damages under present conditions and anticipated flood damages following adoption of the recommended remedial program.

FLOOD CONTROL

Reductions in run-off were calculated by determining the effect of remedial measures upon upland run-off and in turn, upon the volume of floodwaters and the acreage inundated within the flood plains. Application of these reduced flows to future damageable values resulted in probable damages which would occur if the programs were installed. The difference between these damages and those which occur under present watershed conditions is the direct benefit, estimated at $137,217 (table 3). This represents a reduction in flood damages for the watershed as a whole of approximately 21 percent.

Benefits were calculated on the subtributaries separately from those expected in the flood plain of the main stems of Pecan Bayou, Brady Creek, and San Saba River. Flood-control benefits, by tributaries and by types of flood damage affected, are shown in table 3. Benefits for the upper main Colorado area and Pecan Bayou below the Brownwood Dam do not include main-stem benefits for reasons previously indicated.

No values were placed upon indirect and intangible benefits such as enhancement of recreational values, increased income due to prevention of business losses, improvement of public health, increased value of alluvial lands due to the possibility of more intensive use, and the elimination of other minor flood damages which may result from the application of the recommended program. These several items, while significantly affected by the control of floods, are not readily or accurately measurable in monetary terms.

ON-SITE BENEFITS

Conservation or on-site benefits accruing to owners and operators of upland farms and ranches because of increased yields and improved management practices accompanying adoption of the recommended program represent substantial benefits in addition to those resulting directly from the reduction in flood damages. Included in such on-site benefits are increases in gross receipts and decreases in operating expenses.

Since all the land in the Middle Colorado River watershed, for which remedial flood-control measures are recommended, is organized and operated under a farm or ranch economy, it was necessary to evaluate

benefits on the basis of agricultural operating units. In order to arrive at these benefits the organization, income, and expense for each sample type-size farm or ranch unit under present conditions was compared with the organization, income, and expense of the same unit following adoption of the recommended program. Changes in receipts and expenses for the sample type-size farms and ranches were then expanded to the tributary area on the basis of numbers of such farms or ranches.

TABLE 3.—*Estimated average annual flood-control benefits by type and tributary watershed, Middle Colorado River watershed* [1]

Tributary watershed	Crops	Other agricultural	Nonagricultural	Total
Pecan Bayou (above Brownwood Dam)	$33,706	$2,658	$2,766	$39,130
Pecan Bayou (below Brownwood Dam)	13,667	1,423		15,090
Upper main Colorado	35,941	2,953		38,894
Brady Creek	12,745	1,363	81	14,189
San Saba River	21,477	8,019	418	29,914
Total	117,536	16,416	3,265	137,217

[1] Main stem benefits calculated for Pecan Bayou (above Brownwood Dam), San Saba River, and Brady Creek only.

Annual on-site benefits, calculated on this basis, amount to approximately $1,518,600 for the Middle Colorado River watershed as a whole. Benefits for the various tributary areas are as follows:

Tributary:	*Average annual on-site benefit*
Pecan Bayou above Brownwood Dam	$455, 357
Pecan Bayou below Brownwood Dam	125, 225
Upper main Colorado	565, 863
Brady Creek	125, 404
San Saba River	246, 749
Total	1, 518, 598

SECTION VII. COSTS OF PROGRAM

Records of field experiences of technicians and farm operators were used as a basis for calculation of the cost of the remedial program. The acreage affected by each measure was determined by field planning of sample farms and ranches representative of size-type units found in the several physiographic divisions. Quantities of measures requiring installation were determined and unit costs were applied to these quantities. Unit costs for installation and maintenance of the recommended measures are given in table 4. Average costs per acre treated are given for the different tributaries and physiographic divisions in table 5. Table 6 shows the estimated acreage that will participate in the program, the total cost of installation and the annual cost of maintaining the measures by tributaries and physiographic divisions.

Adoption of the recommended measures will inevitably result in some change in the usual purchases and sales of farmers and ranchers. In arriving at total costs of the remedial program, reductions in sales and increases in purchases have been included as "increases in variable costs." They both result in lower net incomes. Likewise, decreases

in purchases and increases in sales were included in on-site benefits since they both result in larger net incomes.

Costs have been divided between those which it is necessary for the Federal Government to bear if the estimated local participation is to be attained and those which farmers and ranchers are expected to bear.

FEDERAL COSTS

Federal cost for installing the remedial program, as shown in table 6, includes all the cost of surveys, plans, supervision, terrace outlets, revegetation of cropland retired to pasture, fencing and water development, and one-half the cost of all terraces. This amounts to $2,693,128 for the watershed as a whole and comprises approximately 80 percent of the total installation costs. All maintenance costs are to be borne by the owners and operators of the land.

PRIVATE COSTS

Farmers and ranchers are expected to bear the cost of installing all contour ridges and furrows and one-half the cost of installing all terraces. This amounts to $666,975 or approximately 20 percent of the total cost of all installation. They also will maintain all remedial measures after installation, at an estimated annual cost of $206,376. In addition, they will be faced with increases in variable costs amounting to $158,116 annually for the watershed as a whole. The increases in variable costs by tributaries are as follows:

Tributary:	*Increase in variable cost*
Pecan Bayou above Brownwood Dam	$36,822
Pecan Bayou below Brownwood Dam	14,195
Upper main Colorado	45,977
Brady Creek	14,021
San Saba River	47,101
Total	158,116

TABLE 4.—*Estimated unit costs for installation and maintenance of recommended measures, Midale Colorado River watershed*

Measure	Unit	Installation	Annual maintenance
1. Level closed-end terraces	Acre	$1.88	$0.22
2. Level open-end terraces		2.30	.33
Outlets for same	Acre	.30	.09
3. Graded terraces	Acre	3.58	.45
Outlets for same	Acre	3.00	.20
4. Revegetation of retired land	Acre	[1] 2.60	
5. Contour furrows	Acre	.80	.16
6. Contour ridges	Acre	2.00	.21
7. Contour listing	Acre	1.00	.20
8. Stock tanks	Acre-foot	100.00	2.00
Fencing	Rod	.60	.03
9. Planning and supervision:			
(*a*) Range land	Acre	.33	
(*b*) Farm land	Acre	1.80	

[1] To be applied to 25 percent of retired cultivated land.

TABLE 5.—*Average installation and annual maintenance cost per acre treated, by tributary and physiographic divisions, middle Colorado River watershed*

Tributary and physiographic division	Installation			Annual maintenance
	Public	Private	Total	
Pecan Bayou above Brownwood Dam:				
Rolling Plains	$2.267	$0.547	$2.814	$0.191
Edwards Plateau	.904	.246	1.150	.078
West Cross Timbers	1.706	.642	2.348	.153
Average	1.736	.489	2.225	.149
Pecan Bayou below Brownwood Dam:				
West Cross Timbers	1.579	.486	2.065	.123
Grand Prairie	.941	.240	1.181	.080
Average	1.210	.343	1.533	.098
Upper main Colorado:				
Rolling Plains	2.125	.533	2.658	.191
West Cross Timbers	1.500	.533	2.033	.123
Edwards Plateau	.894	.263	1.157	.080
Average	1.599	.450	2.049	.141
Brady Creek:				
Rolling Plains	1.817	.457	2.274	.161
Edwards Plateau	.473	.108	.581	.021
Average	.787	.189	.976	.054
San Saba River:				
Edwards Plateau	.515	.050	.565	.015
Central Basin	1.132	.115	1.247	.067
West Cross Timbers	1.806	.297	2.103	.125
Average	.634	.068	.702	.025
Entire watershed average	1.178	.292	1.470	.090

TABLE 6.—*Cost of installation and maintenance of recommended remedial measures, by tributary and physiographic divisions, Middle Colorado River watershed*

Tributary and physiographic division	Participating area, acres	Installation cost		Annual maintenance, private	Average annual costs [1]		
		Federal	Private		Federal	Private	Total
Pecan Bayou above Brownwood Dam:							
Rolling Plains	210,983	$478,346	$115,331	$40,288	$16,742	$44,324	$61,066
Edwards Plateau	130,100	117,609	32,048	10,172	4,116	11,294	15,410
West Cross Timbers	128,775	219,640	82,685	19,750	7,688	22,644	30,332
Total	469,858	815,595	230,064	70,210	28,546	78,262	106,808
Pecan Bayou below Brownwood Dam:							
West Cross Timbers	87,150	137,632	42,354	10,701	4,817	12,183	17,000
Grand Prairie	120,254	113,200	28,829	9,680	3,962	10,689	14,651
Total	207,404	250,832	71,183	20,381	8,779	22,872	31,651
Upper main Colorado:							
Rolling Plains	269,016	571,782	143,250	51,456	20,012	56,470	76,482
West Cross Timbers	138,524	207,826	73,835	17,010	7,274	19,594	26,868
Edwards Plateau	181,285	162,061	47,653	14,593	5,672	16,261	21,933
Total	588,825	941,669	264,738	83,059	32,958	92,325	125,283
Brady Creek:							
Rolling Plains	59,999	109,031	27,416	9,674	3,816	10,633	14,449
Edwards Plateau	197,135	93,253	21,306	4,167	3,264	4,913	8,177
Total	257,134	202,284	48,722	13,841	7,080	15,546	22,626
San Saba River:							
Edwards Plateau	662,909	341,641	33,049	9,744	11,957	10,901	22,858
Central Basin	56,194	63,626	6,466	3,780	2,227	4,006	6,233
West Cross Timbers	42,902	77,481	12,753	5,361	2,712	5,807	8,519
Total	762,005	482,748	52,268	18,885	16,896	20,714	37,610
Grand total	2,285,226	2,693,128	66,975	206,376	94,259	229,719	323,978

[1] Federal costs include interest on installation at 3½ percent. Private costs include interest on installation at 3½ percent plus annual maintenance.

SECTION VIII. COMPARISON OF COSTS AND BENEFITS OF THE RECOMMENDED PROGRAM

Installation of the remedial program on 50 percent of the farms and ranches of the watershed is expected to require a period of 20 years. Maximum benefits from the adoption of the measures on any individual farm or ranch, however, are expected to be attained by the end of 10 years after installation on that farm or ranch. In order to allow for expenditure of the funds over a 20-year period and for a 10-year period of adjustment both costs and benefits were discounted at 3½ percent per annum according to the length of the period involved.

Annual costs and benefits of the recommended program are shown by tributaries in table 7. It should be noted that the rough stony areas of the Edwards Plateau and Central Basin are not included in the treatment area and that flood control benefits do not include any benefit to the main stems of the Colorado River and Pecan Bayou below Brownwood Dam.

TOTAL COSTS AND TOTAL BENEFITS

Average annual cost of the recommended flood control program is $482,094 (table 7). Of this amount $94,259, or about 20 percent, is to be borne by the Federal Government, and the remaining $387,835, or about 80 percent, is to be paid by owners and operators of cooperating ranches and farms.

Total benefits from the program amount to $1,655,815 annually, of which flood control benefits, $137,217, comprise approximately 8 percent and on-site or farm income benefits, $1,518,598, or 92 percent. Total benefits exceed total costs in each of the tributary areas. The ratio of total benefits to total costs is 3.44 to 1.00 for the watershed as a whole.

FLOOD CONTROL BENEFITS AND FEDERAL COSTS

The average annual Federal cost of the recommended program is estimated as $94,259 while direct flood-control benefits are estimated as $137,217 annually. The ratio of flood-control benefits to Federal costs therefore is 1.46 to 1.00.

Flood-control benefits exceed Federal costs in each tributary watershed. In all tributary areas, except the upper main Colorado the difference is substantial.

TABLE 7.—*Average annual benefits, costs and cost-benefit ratios by tributary watersheds, Middle Colorado River watershed*

Tributary watershed	Participating area	Average annual benefits			Average annual costs			Flood control benefit per dollar Federal cost	Total benefit per dollar total cost
		Flood control	Conservation [1]	Total	Federal [2]	Private [3]	Total		
	Acres	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*		
Pecan Bayou above Brownwood Dam	469,858	39,130	455,357	494,487	28,546	115,084	143,630	1.37	3.43
Pecan Bayou below Brownwood Dam	207,404	15,090	125,225	140,315	8,779	37,067	45,846	1.72	3.06
Upper main Colorado	588,825	38,894	565,863	604,757	32,958	138,302	171,260	1.18	3.53
Brady Creek	257,134	14,189	125,404	139,593	7,080	29,567	36,647	2.00	3.81
San Saba River	762,005	[4] 29,914	246,749	276,663	16,896	67,815	84,711	[4] 1.77	3.27
Grand total	2,285,226	137,217	1,518,598	1,655,815	94,259	387,835	482,094	1.46	3.44

[1] Includes increases in receipts and decreases in operating expenses.
[2] Interest on installation.
[3] Interest on installation of measures, annual maintenance, decreases in receipts, and increases in operating expenses.
[4] Includes $6,175 benefit on main stem. If reservoir is constructed at Menard and it is assumed that it will prevent all flood damage on the main stem of the San Saba and that the $6,175 benefit will not accrue to the program herein evaluated the benefit-cost ratio would be favorable to the extent of $1.40 benefit for each $1 of Federal cost. Actually, if the reservoir is constructed there would still be an appreciable main stem flood-control benefit accruing to the watershed program.

○

APHIC DIVISIONS AND FLOOD DAMAGE INVESTIGATIONS
LE COLORADO WATERSHED-TEXAS
FIGURE 1

LEGEND

OS

REA BOUNDARY

COLORADO

K

NATURAL PHYSIOGRAPHIC DIVISIONS

- ROLLING PLAINS
- CENTRAL BASIN-ROLLING
- CROSS TIMBERS.
- GRAND PRAIRIE
- EDWARDS PLATEAU-ROLLING GRAVELLY.

LOOD DAMAGE INVESTIGATIONS

- LOW DAMAGE AREAS
- MODERATE DAMAGE AREAS.
- HIGH DAMAGE AREAS.
- D| LIMITS OF DETAILED DAMAGE STUDY
- R| LIMITS OF RECONNAISSANCE DAMAGE STUDY

Latitude 36° 31° 26°

10 0 10 20 30 40 50

SCALE OF MILES

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NATURAL PHYSIOGRAPHIC DIVISIONS AND FLOOD DAMAGE INVESTIGATIONS

MIDDLE COLORADO WATERSHED-TEXAS

FIGURE 1

LEGEND

KEY TO WATERSHEDS

- TRIBUTARY AREA BOUNDARY
- (1) PECAN BAYOU
- (2) UPPER MAIN COLORADO
- (3) BRADY CREEK
- (4) SAN SABA

NATURAL PHYSIOGRAPHIC DIVISIONS

- ROLLING PLAINS
- CENTRAL BASIN-ROLLING
- CROSS TIMBERS.
- GRAND PRAIRIE
- EDWARDS PLATEAU-ROLLING GRAVELLY

FLOOD DAMAGE INVESTIGATIONS

- LOW DAMAGE AREAS
- MODERATE DAMAGE AREAS
- HIGH DAMAGE AREAS
- |D D| LIMITS OF DETAILED DAMAGE STUDY
- |R R| LIMITS OF RECONNAISSANCE DAMAGE STUDY

Latitude 36° 31° 26°

10 0 10 20 30 40 50

SCALE OF MILES

(Follows page 25)

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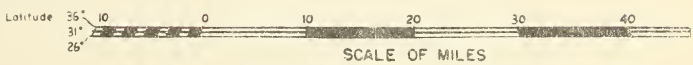
SOIL CONSERVATION DISTRICTS

IDDLE COLORADO WATERSHED—TEXAS

FIGURE-2

LEGEND

ED & RECEIVING ASSISTANCE	AREA WITHIN WATERSHED SQUARE MILES
ENTRAL COLORADO	1812
ONCHO	888
LDORADO-DIVIDE	477
ROWN-MILLS	1339
PPER LEON	40
ED & NOT RECEIVING ASSISTANCE	
ABA-BRADY	1414
T ORGANIZED ROBABLE LOCATION & SIZE	
-KIMBLE	862
-LLANO	182
-EDWARDS	143
S	32



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(Follows page 25)

SOIL CONSERVATION DISTRICTS

MIDDLE COLORADO WATERSHED—TEXAS

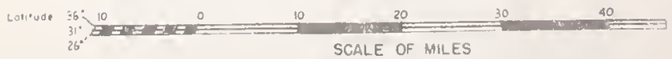
FIGURE-2

LEGEND

ORGANIZED & RECEIVING ASSISTANCE	AREA WITHIN WATERSHED SQUARE MILES
SCD-5 CENTRAL COLORADO	1812
SCD-34 CONCHO	888
SCD-212 ELDORADO-DIVIDE	477
SCD-523 BROWN-MILLS	1339
SCD-525 UPPER LEON	40

ORGANIZED & NOT RECEIVING ASSISTANCE	
214 SAN SABA-BRADY	1414

NOT YET ORGANIZED PROBABLE LOCATION & SIZE	
3 MENARD-KIMBLE	862
4 MASON-LLANO	182
5 SUTTON-EDWARDS	143
6 RUNNELS	32



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OMMENDED LAND UTILIZATION AND TREATMENT BASED ON
CURRENCE OF GENERAL LAND USE CAPABILITY CLASSES
MIDDLE COLORADO WATERSHED - TEXAS
FIGURE 3

L E G E N D

UITABLE FOR CROP FARMS:

Suitable for crop production without special practices.

Suitable for crop production with simple practices.

Suitable for crop production with complex practices.

UITABLE FOR LIVESTOCK FARMS:

Suitable for livestock production and requiring moderate restrictions in land use and some special practices on cultivated and pasture land.

UITABLE FOR RANCHES:

Land suitable for livestock production and requiring moderate restrictions in land use, special practices on cultivated land, and limited special practices on pasture land.

Land suitable for livestock production and requiring severe restrictions in land use, complex practices on cultivated land, and limited special practices on pasture land.

Latitude 36° 31° 26°

10 0 10 20 30 40

SCALE OF MILES

U. S. GOVERNMENT PRINTING OFFICE 1944 O - 90053

(Follows page 25)

RECOMMENDED LAND UTILIZATION AND TREATMENT BASED ON OCCURRENCE OF GENERAL LAND USE CAPABILITY CLASSES
MIDDLE COLORADO WATERSHED - TEXAS
FIGURE 3

L E G E N D

LAND SUITABLE FOR CROP FARMS:

CLASS

I — Suitable for crop production without special practices

II — Suitable for crop production with simple practices

III — Suitable for crop production with complex practices

LAND SUITABLE FOR LIVESTOCK FARMS:

IV — Suitable for livestock production and requiring moderate restrictions in land use and some special practices on cultivated and pasture land.

LAND SUITABLE FOR RANCHES:

VI — Land suitable for livestock production and requiring moderate restrictions in land use, special practices on cultivated land, and limited special practices on pasture land

VII — Land suitable for livestock production and requiring severe restrictions in land use, complex practices on cultivated land, and limited special practices on pasture land.

Latitude 36° 31° 26°

10 0 10 20 30 40

SCALE OF MILES

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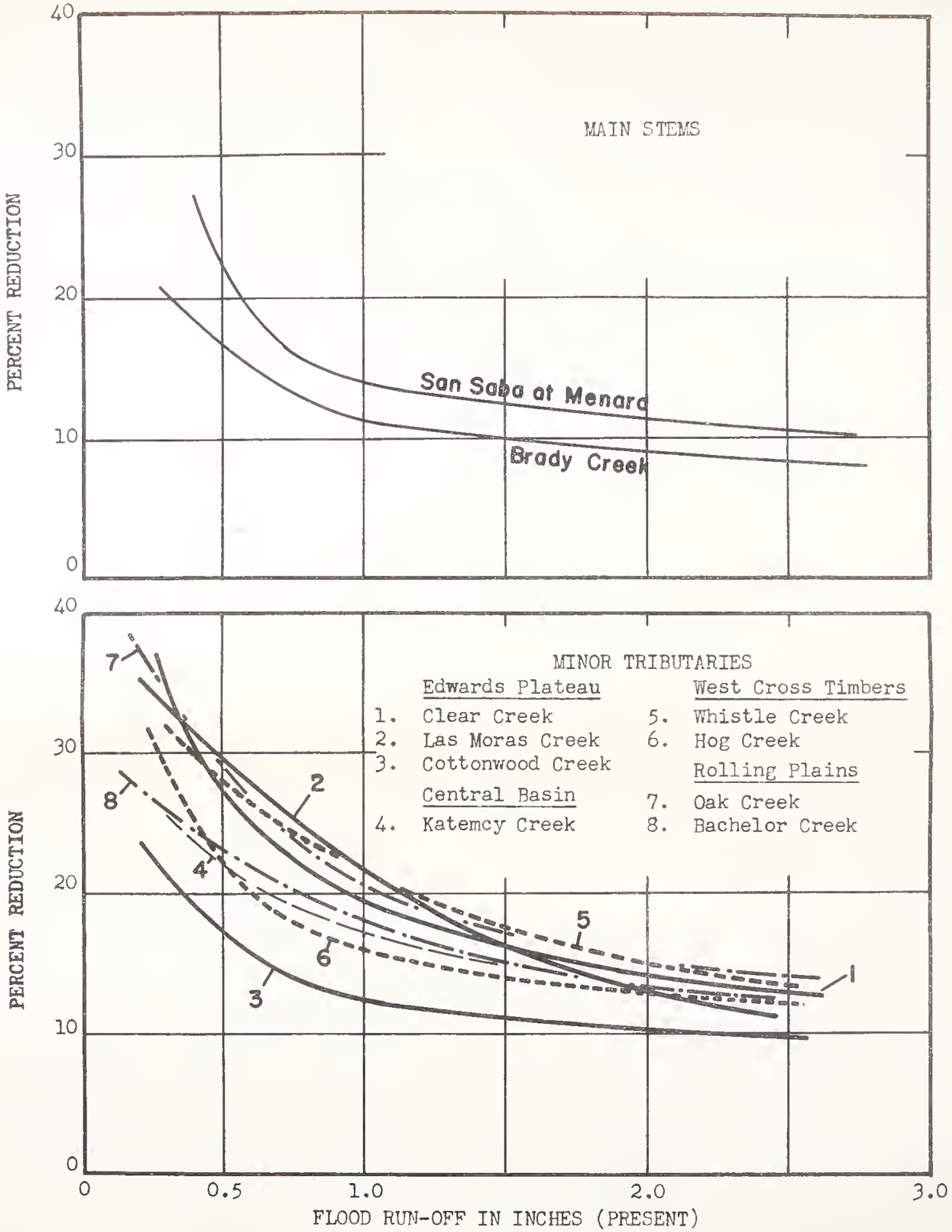

FIGURE 4. -- AVERAGE REDUCTIONS IN FLOOD RUN-OFF

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